EFFICACY OF THE METHODS USED IN AN INTEGRATED PROGRAM TO DETER THE DISPERSAL OF BROWN TREE SNAKES FROM GUAM

Richard M. Engeman,[1] Michael A. Linnell,[2] Daniel S. Vice[3] and Mikel E. Pitzler[3]

[1]National Wildlife Research Center, 1716 Heath Pkwy, Fort Collins, CO 80524, USA
[2]USDA/APHIS/WS, 720 O'Leary St, NW, Olympia, WA 98502, USA
[3]USDA/APHIS/WS, 1060 Route 16, Suite 103-C, Barrigada Heights, GU 96921, USA

ABSTRACT

The inadvertent introduction of the brown tree snake (*Boiga irregularis*) to Guam has resulted in the extirpation of most of the island's native terrestrial vertebrates, has presented a health hazard to small children, and also has produced an economic problem. Deterring its dispersal through Guam's cargo traffic has become a high environmental priority, and the efficacy of the control methods used towards this objective are reported here. Detector dog inspections of cargo and population reductions in the vicinities of cargo staging areas through trapping and spotlight searches of fences were quantitatively evaluated. Trapping effectively removed snake populations in forested plots of land characteristic of port areas. Perimeter trapping on those plots was not only the most labor-efficient strategy, but also the most effective. Re-invasion into trapped plots was slow. Extensive snake use of fences makes spotlight searches a valuable control tool and a promising means of detecting incipient populations. The preponderance of snakes found by detector dogs were in position to be transported to vulnerable locations. With routine discrete plantings of snakes (in escape-proof containers) in cargo, high efficacy was achieved by the detector dogs. Identification of transportation means offering brown tree snakes the most likely courses for departing Guam and arriving alive at a vulnerable location, coupled with strategic use and integration of control methods, minimizes the risk of their dispersal from Guam.

INTRODUCTION

The brown tree snake (*Boiga irregularis*) on Guam is a severe example of the effects that an introduced predator can have on insular populations of native fauna (Savidge 1987). It was brought to Guam accidentally through post World War II shipments from New Guinea (Rodda et al. 1992) and its populations have attained extraordinary densities (Rodda et al 1992). They have decimated the native fauna. Currently, only 3 of the 12 species of forest birds survive in the wild, with one of those on the verge of elimination. Bat populations declined along with bird populations. Guam populations of Mariana fruit bat (*Pteropus mariannus*), already impacted by hunting, were further decimated by snake predation. Two other bat species disappeared by the early 1970's from unidentified causes (Wiles et al. 1995). Only one of the 12 native species of lizards on Guam occur in densities similar to nearby snake-free islands (Rodda and Fritts 1992).

Guam also has suffered economical and social consequences from brown tree snake introduction. Brown tree snakes have become agricultural pests through depredations on poultry and other small domesticated animals (Fritts and McCoid 1991). They climb utility poles and wires, causing frequent power failures resulting in millions of dollars of damaged equipment, lost productivity, and repair costs (Fritts et al. 1987). Furthermore, the brown tree snake is mildly venomous and readily enters buildings where it is a health hazard to small children, who are less able to defend themselves and have been subjects of life-threatening snake bite incidents (Fritts et al. 1990).

The brown tree snake is well-suited for transport to, and establishment at, other locations. They are agile climbers that seek refuge from heat and light during daylight. Cargo, shipping containers and transport vessels may offer ready daytime refugia. They are opportunistic feeders that have been observed to consume a highly varied diet (Savidge 1987, Rodda et al. 1997, Linnell et al. 1997). These elements, coupled with Guam's position as a focal point for commercial and military shipments of cargo and passengers throughout the Pacific, presents an acute and chronic threat for the further dispersal. Sightings have been documented on many Pacific islands, with an incipient population speculated to exist on Saipan in the Commonwealth of the Northern Mariana Islands (CNMI) (McCoid 1994). Federal control efforts were implemented in 1993 to deter the accidental spread of brown tree snakes from Guam, and a series of studies since 1995 has assessed the effectiveness of the control methods.

CONTROL METHODS DESCRIPTIONS

Three fundamental control methods are employed to minimize brown tree snake dispersal: 1) detector dog searches of outbound cargo, and snake removal to create low population buffer areas in vicinities cargo staging areas by 2) trapping and 3) nighttime spotlight searches of fence lines. The methods complement each other and each has specific nuances for successful application. The primary areas on Guam targeted for snake control include commercial and Naval wharf areas, Won Pat International Airport area, the flight line and cargo staging areas at Andersen Air Force Base (AAFB), commercial packers and shippers, and military housing.

Trapping

Trapping around cargo staging areas is central to the integrated wildlife damage management program. Snakes are captured using funnel traps (i.e., minnow or crayfish traps), with one-way doors installed at the entrances. A live mouse, protected in an interior cage, serves as an attractant. A 20 m separation between traps typically is used for three basic trap placement strategies: 1) perimeter trapping, which encloses a plot with a trap line on the forest edge; 2) interior trapping, which has traps placed along trails through the plot interior, and is the most labor-intensive strategy because it requires cutting trails and traversing the forest without a vehicle; and 3) boundary trapping, which places the traps along one edge of a plot, is used where plots cannot be easily defined by physical features (e.g., adjacent to contiguous jungle), or to maintain low populations after a more thorough trapping regimen has been applied.

Habitat adjacent to port, cargo packing and cargo staging areas is largely comprised of remnant plots of jungle vegetation, fragmented by commercial, industrial or military development. Trap lines in the highest risk areas are maintained on a permanent basis. Other trap lines are moved after captures remain near zero for several months, allowing a fixed number of traps to be used over a wider area.

Spotlight Searches of Fence Lines

Most port and other cargo staging locations are surrounded by extensive fence lines. Habitat adjacent to the fences is highly variable, ranging from manicured lawns to contiguous forest. Typically, fences are 2.4 m chain-link with 3 parallel strands of barbed wire on 45° outriggers above the chain link. Usually, a horizontal bar supports the top of the chain link. Fences at AAFB generally are constructed with a steel support cable woven through the top of the chain link. Most fences have suitable topography and cleared vegetation on at least one side to permit vehicle access. Searches are conducted by illuminating fences with 250,000 candlepower spotlights from slowly moving vehicles.

Spotlight searches of fences have been an efficient way to remove large numbers of snakes in the vicinity of ports (USDA/APHIS Wildlife Services data 1994-1997). In some areas snake traps are heavily vandalized or damaged by animals, to such an extent that a trapping program is impractical to maintain. Then, spotlighting fences may be the only effective control tool available for removing snakes.

Detector Dog Inspections of Cargo

Trapping and spotlight searches effectively capture large numbers of snakes, but some snakes are able to stow away in cargo. To detect snakes stowed in cargo, teams of handlers and their uniquely assigned dogs

(Jack Russell terriers) inspect outbound cargo, cargo staging areas, and transport vessels identified as posing a risk for introduction of a brown tree snake to a vulnerable location. A variety of commercial and military locations are inspected and three shifts of handlers and their dogs are available 24 hours for conducting inspections. Dog teams serve in a cooperative, rather than regulatory, capacity and, therefore, are not stationed at ports of entry/exit. Their use in cargo is the result of cooperative arrangements and coordination with agencies, organizations, and companies transporting cargo from Guam. A thorough understanding of cargo transport from Guam is necessary to effectively apply the dogs.

CARGO RISK ASSESSMENT

Cargo inspections are prioritized according to the type, amount, frequency (seasonal and daily), and primary destinations of the cargo leaving Guam. Other risk prioritization factors include packing, storage (cross contamination potential), storage facility location and environment, transportation method, origination points and transit time. Continually monitoring this information facilitates optimization of trapping, spotlight searches, and detector dog inspections within the available resources. Snake survival in cargo is likely related to transit time and exposure to heat in transit. Survivorship is probably greater for snakes in cargo containers not exposed to the sun and for those snakes located near the centers of containers. Sealed shipping containers can get very hot inside and snakes probably could not endure these conditions for extended periods, particularly along container peripheries. This affirms the need to search cargo before it is containerized, and suggests that containerized cargo shipped overseas by surface probably is of less risk than cargo of similar contents sent by air to the same destinations.

EFFICACY ASSESSMENT RESULTS

Trapping

Trap construction - The flaps at trap entrances are essential components for capturing snakes and preventing subsequent escapes. Stamped metal flaps, combined with a system to prevent lateral movement of the hinge pin, provided high capture rates with small probabilities of jams (0.002 jams/trap-night). Flaps on that hinge design close even with 75-80° trap rotation along the horizontal axis (Linnell et al. 1998). Subsequent research indicated that entrance rates would be highest with flaps permitting high visibility of the mouse (Shivik 1997). Also, doors must resist opening by wind and withstand damage from nontarget captures like rats and coconut crabs. Thus, flaps now are constructed of heavy gauge wire mesh, with the same hinge design and produce similar capture rates.

Trap Placement Strategy - Capture records from operational control indicated that a perimeter trap line around a plot was an effective, labor-efficient means for snake removal from plots as large as 8 ha (Engeman et al. 1998c). Ensuing studies have investigated different trap placement strategies. Plots with both perimeter and interior trapping resulted in 3 times the capture rate for perimeter traps as interior traps. Engeman et al. (1998c) speculated that when snakes encounter the forest edge, they tend to stay along its perimeter. This results in a higher probability of snakes encountering traps on the forest perimeter than in its interior.

Snake Population Reductions and Recovery - Brown tree snake population levels remaining after extended operational trapping were examined on two plots of land (Engeman et al. 1998a). These plots were subjected to further trapping at a much greater intensity than the operational trapping levels. Trapping was terminated after at least 4 weeks without a capture. Only 2 snakes were captured in a 4.2 ha plot and 4 were captured in a 6.5 ha plot. Operational trapping methods were concluded to be highly effective at reducing snake populations in this area where optimal habitat occurs in a patchy distribution (Engeman et al. 1998a). Population recovery rates in those plots were slow, as they later produced only 25 and 17 captures, respectively, in intensive trapping efforts 8 and 11 months after population removal (0.75 and 0.24 snakes/ha/mo reinvasion rates).

Spotlight Searches of Fence Lines

Because snakes encountering a fence usually climb the fence rather than continuing through it (Rodda 1991), searches of the fences by spotlight complement the trapping efforts and forms an important component of the integrated control program. Snakes were concentrated near the fence top (Rodda 1991). We characterized over 600 snake captures during spotlight searches of fences. Greater proportions of snakes were found concentrated at the top or on the wires than observed by Rodda (1991). Fences supported by horizontal top bars had most (75%) snakes captured on the top bar or the strands of barbed wire above it. Inclusion of the top third of the chain link with the top bar and barbed wires accounted for 92% of the captures, while fences without the top bar concentrated snakes at the top to a slightly lesser extent (82%). Snakes found on the fences were usually resting or traveling (horizontal position), rather than ascending or descending.

With the snakes concentrating at fences tops, a faster search that still detects a high proportion of the snakes (say 65-90%) could be conducted by concentrating on just the top of the fence. Regular spotlight searches of fences surrounding plots of land may serve in a fashion similar to perimeter trapping, because snakes tend to remain in the same area (M. Tobin, R. Sugihara, personal communications) and re-invade unoccupied areas slowly.

Fences can be designed and maintained to effectively assist in brown tree snake capture and control. Chain link fences with a bar on top and parallel strands of wire above appear to concentrate snakes at the top of the fence, increasing spotlight search efficiency. Fences subject to searches should be maintained free of vegetation and have a mowed buffer between them and forest. Vegetation on the fence makes it difficult to observe snakes, while a mowed buffer between the fence and the forest facilitates searches from vehicles and promotes the fence climbing behavior.

Rodda (1991, 1992) indicated that brown tree snakes primarily use fences to forage for geckos. However, a large portion of the snakes are captured from the wires above the chain link, where lizards are less likely to be encountered. This suggests that snakes also use the top bar and wires as continuous, stable pathways for movement. Accordingly, spotlight searches may be valuable means for detecting and capturing members of incipient populations, especially since the trapping efficacy demonstrated on Guam could be much reduced in a prey rich environment.

Detector Dog Inspections of Cargo

Operational records for brown tree snakes detected during dog inspections indicated that 80% of the discovered snakes were at high risk for export, with Hawaii and Micronesian islands, the two most frequently identified potential destinations (Engeman et al. 1998b). The efficacy of the teams of handlers and their dogs for finding brown tree snakes was investigated by planting brown tree snakes (in escape-proof containers) in cargo without the knowledge of the handlers responsible for the inspections. When an observer attended the inspection, 80% of the planted snakes were located. Without an attending observer present, 70% of the planted snakes were discovered, but only after such plantings had become routine. In the 4 month period prior to that, efficacy was nearly 50% less. The reasons some snakes were not found included an insufficient search pattern by the handler, or the dog giving no discernable response to a snake. The 70% detection efficacy rate hypothetically could be raised by an amount similar to the rate of insufficient search patterns (around 15%). Conversely, discontinuation of the trials with planted snakes likely would lead to decreased attentiveness to procedures and a subsequent decrease in efficacy.

DEVELOPING ADDITIONAL CONTROL METHODS

A variety of investigations have been aimed at developing additional control tools and at improving current methods. Several cargo fumigants have been found effective against brown tree snakes (Savarie et al. 1998) and the registration label for methyl bromide was expanded to include brown tree snakes.

However, the expense and logistics for application of these products minimizes demand. Additionally, many chemicals have been examined for oral and dermal toxicity to brown tree snakes (Brooks et al. 1998a, Brooks et al. 1998b). Large-scale toxicant applications could be implemented if effective, safe and snake-specific delivery systems were developed, and an effective, long-lasting lure was produced.

There appears to be a reasonable potential for developing an inanimate brown tree snake attractant, if the correct chemical cues can be defined. Most promising, Shivik (1998) and Shivik and Clark (1997) demonstrated that carrion in the form of a dead mouse can produce the same level of attraction to brown tree snakes as the live mouse used for trapping. Unfortunately in Guam's climate, this attraction is effective only for 2-3 days, and is reduced during the wet season. An artificial lure that produces a 7-day effect would greatly reduce labor for maintaining snake traps and is key to development of dermal toxicant delivery systems and baits for oral toxicants.

Brown tree snakes are remarkable climbers, but suitably effective barriers could prevent brown tree snake intrusion into other areas. Cargo staging areas on Guam and inbound cargo areas at vulnerable destinations could be protected, as could be endangered species habitats, power stations, and poultry production. Besides snake climbing abilities, barrier use is challenged by breaches from typhoons, large animals (pigs, dogs, deer), rats, and vegetation overgrowth. Tests of barrier designs are currently underway (G. Rodda, personal communication) and barriers have been installed to contain incoming brown tree snakes at ports of entry in the CNMI. Temporary barriers have been used at AAFB.

CONCLUSIONS

The control methods of trapping, spotlight searches of fences, and detector dog inspections of cargo each have been found to be effective at reducing chances of brown tree snakes accessing and stowing away in transportation network from Guam. Integration of the control methods maximizes their efficacy. Continued refinements and optimization of application strategies should show steady improvement in effectiveness. Better understanding of cargo flows from Guam, snake survivability in transit from Guam, coupled with a public awareness to cooperate with snake control efforts, should allow more precise control strategies and more productive application of control methods. Additional methods that are practical to apply and complement existing tools probably would further prevent brown tree snakes from dispersing from Guam.

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